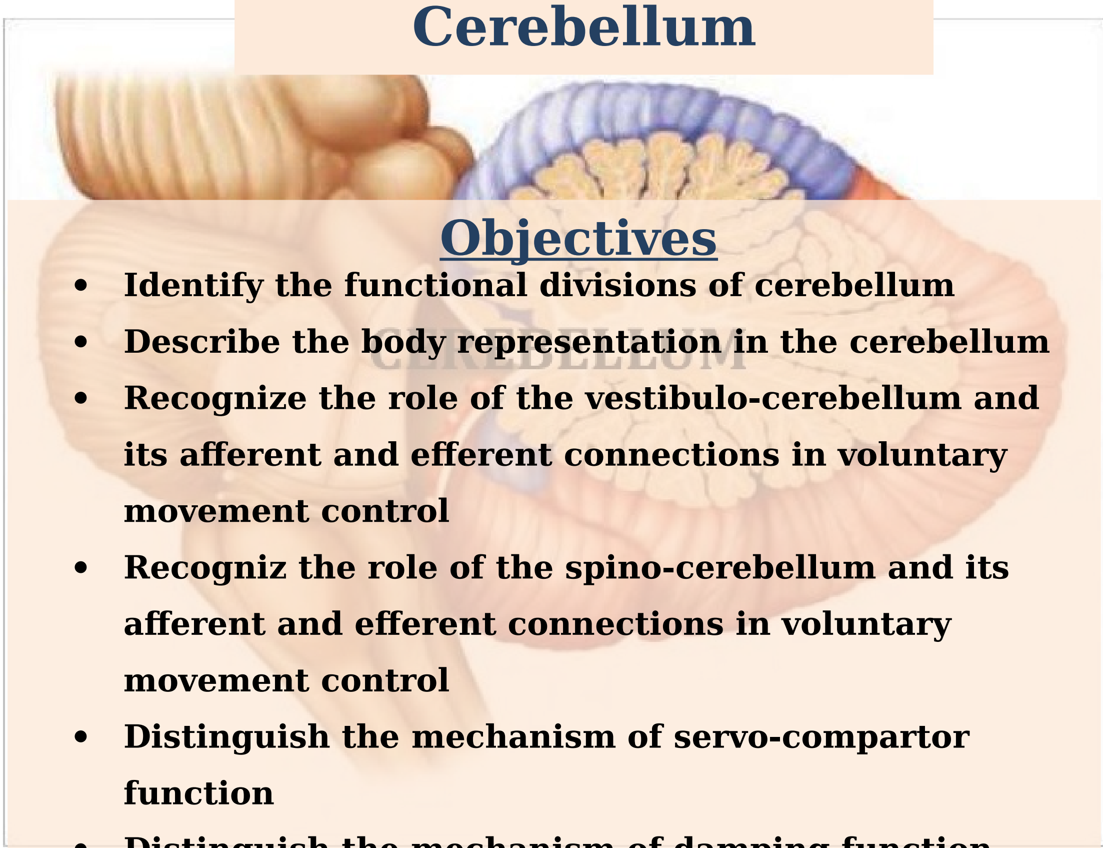
Lecture 17,18
Cerebellum



Objectives

- **Identify the functional divisions of cerebellum**
- **Describe the body representation in the cerebellum**
- **Recognize the role of the vestibulo-cerebellum and its afferent and efferent connections in voluntary movement control**
- **Recogniz the role of the spino-cerebellum and its afferent and efferent connections in voluntary movement control**
- **Distinguish the mechanism of servo-compartor function**
- **Distinguish the mechanism of damping function**
- **Distinguish the mechanism of ballistic movement**
- **Recognize the role of the cerebro-cerebellum and its afferent and efferent connections in voluntary movement control**

The cerebellum

- The little brain {Silent brain} only **10 % total volume** of the brain but more than half of all its neurons.
- Receive sensory input but has **no role in sensory awareness**: lesion doesn't result in sensory loss
- Influence motor behavior **doesn't initiate movement:** lesion doesn't cause paralysis
- Cerebellum plays a vital role during **rapid muscular activities** such as running, typing, playing the piano, and talking
- It is formed of **2 cerebellar hemispheres** connected by vermis
- Each hemisphere controls the **same side** of the body

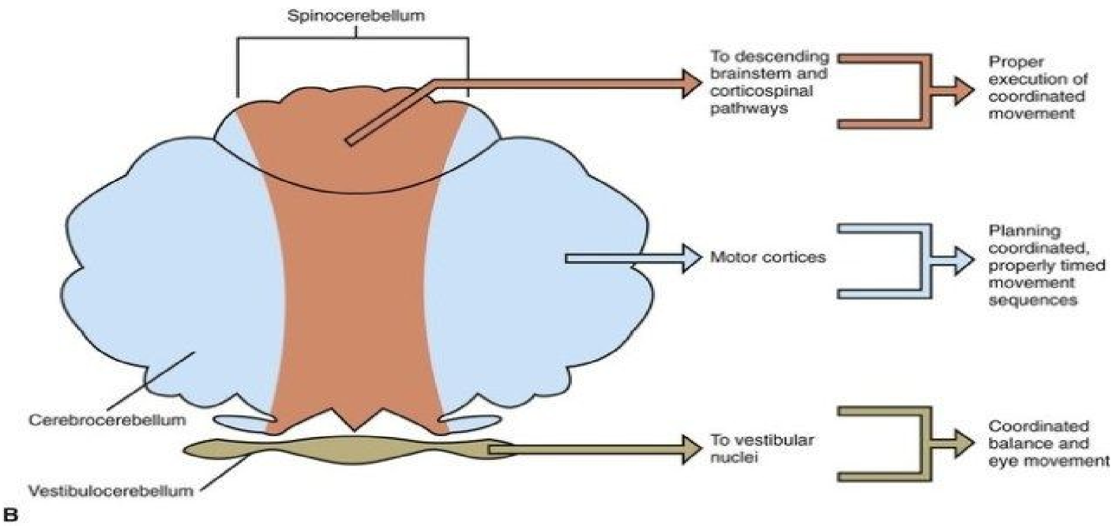


Figure (1): functional divisions of cerebellum

1-Functional divisions of cerebellum

Vestibulo-cerebellum {Archicerebellum }	**Spino-cerebellum {Paleocerebellum }**	**Cerebro-cerebellum {Neo-cerebellum}**
flocculonodular lobe+ part of vermis	**Vermis+ intermediate zones of cerebellar hemispheres**	**Lateral parts of cerebellar hemispheres**

1- Maintain equilibrium **2- Control eye movements.**	**Servo comparator function, Co-ordination of the on-going movement**	**Planning, programming**

2-Topographic representation in cerebellum:

- Body is represented into 2 maps
- An upright map in the posterior lobe and an upside down in the anterior lobe.
- Axial parts are represented in vermis, limbs and face are represented in the intermediate zones.

3- Cerebellum connections

I-Cerebellum is connected to other brain areas through three **cerebellar peduncles: superior, middle, inferior.**

II-Cerebellar input:

All afferents to the cerebellum end on the deep cerebellum nuclei (DCN) and on cerebellar cortex.

III- Main cerebellar output:

Cerebellar efferent arise from the **deep cerebellar nuclei**:

- Three deep cerebellar nuclei are fastigial, interposed and dentate nuclei.
- Also, the vestibular nuclei in the medulla function act as deep cerebellar nuclei because they are directly connected with the cortex of the flocculonodular lobe.
- Deep cerebellar nuclei receive signals from two sources: (1) the cerebellar cortex and

(2) the deep sensory afferent tracts to the cerebellum.

- **<u>The fastigial nucleus</u>**: projects from the vermis to the medullary and pontine reticular formation of the brain stem and to the vestibular nuclei. They maintain equilibrium and posture.

- **<u>The interposed nuclei:</u>** projects from the intermediate zone to the ventro-anterior nuclei of the thalamus and then to the cerebral cortex or to the contralateral red nucleus (the origin of the rubrospinal tract). It coordinates the reciprocal contractions of agonist and antagonist muscles.

- **<u>The dentate nucleus:</u>** projects from the lateral hemisphere to the contralateral red nucleus and the ventrolateral (VL) thalamic nucleus. It helps in planning sequential motor activities.

4- <u>Physiological functions of the cerebellum:</u>

<u>Vestibulocerebellum</u>

I- <u>Afferents:</u>

<u>Signal</u>	**<u>origin</u>**	**<u>tract</u>**
Visual , auditory	Tectum (superior and inferior colliculi)	Tecto-cerebellar tract
Body posture, equilibrium	Vestibular nuclei in medulla or vestibular receptors in labryinth	Vestibulo-cerebellar tract
Propioception	Muscles (muscle spindle)	Dorsal spino-cerebellar tract

		(Afference copy)
	gracile, cuneate nuclei	cuneo-cerebellar tract

II- Efferent:

origin	Fastigial nucleus
target	▪ Reticular formation ▪ Vestibular nuclei in medulla
functi on	▪ Reticulospinal and vestibulospinal tracts Control axial and proximal muscles tone to maintain balance and equilibrium ▪ from vestibular nucleus to medial longitudinal bundle to external occular muscles ▪ Co-ordinate eye and head movements to maintain clear vision.

III- Function:

1- Maintain **equilibrium, c**ontrol balance between agonist and antagonist muscles during **rapid change in body position**.

2-Control eye movements: Saccades and Pursuit movements and **co-ordinate eye and head movements**

IV-Lesion:

Trunkal ataxia and Nystagmus

Spinocerebellum

I- Afferents:

Signal	origin	tract
Intended cortical motor plan	Motor cortex, somatosensory, association areas	Cortico-ponto-cerebellar pathway
Motor signals that reach anterior horn cells from cortico-spinal		Ventral spino-cerebellar tract (efference copy)
Proprioception	Muscles (muscle spindle)	Dorsal spino-cerebellar tract (Afference copy)

	gracile, cuneate nuclei	Cuneo-cerebellar tract
Muscle tone, movements	Reticular formation (receive signals from cortex + spinal cord}	Reticulo-cerebellar tract
<u>Comparative signals:</u> between motor cortex, basal ganglia and spinal cord	Inferior olivary nucleus	Olivo-cerebellar tract (Climbing fibers)

II- <u>Efferent:</u>

origin	Nucleus interpositus.
Target	▪ Red nucleus ▪ Thalamus ▪ Reticular formation and vestibular nucleus
Function	▪ **<u>Rubrospinal tract</u>** ▪ **<u>Thalamocortical tract:</u>** then corticospinal tract, to control muscle contraction ▪ **<u>Reticulospinal and vestibulospinal tracts:</u>** To control muscles tone

III- <u>Physiological function:</u>

<u>Coordinate the ongoing movement</u>

1. <u>Servo-compartor function:</u>

- Spinocerebellum **<u>compare</u>** signals from the motor cortex that carry the intended motor plan with actual muscle performance during the movement (Proprioceptive feedback signals).
- Spinocerebellum detect error then send corrective signals from the interpositus nucleus through red nucleus and thalamus.

2. <u>Damping function:</u>

- It is the ability of the cerebellum to end movement suddenly (precisely) at the intended point, without any jerkiness or oscillations. It cuts off extra impulses to perform smooth accurate movements.
- <u>*Mechanism:*</u>

By cerebellar stretch reflex: increasing the stretch reflex sensitivity in the antagonistic muscle during movements.

3. Coordinate rapid ballistic movement:

- Rapid ballistic movements are the rapid movements preplanned to go to specific time then stops as fingers typing or saccadic eye movements during reading.
- They are controlled through the turn on/off mossy fiber circuit.

A- Turn on signals

- At first, cortico-ponto cerebellar mossy fibers carrying the intended motor plan will stimulate deep nuclei and facilitate movement after few m sec.

B-Turn off signals

- Parallel fibers are very slow fibers
- Take time to summate and excite purkinjie cells

So, at the end of planned movement mossy fibers would have excited granular cells that excite purkinjie cells that inhibit deep nuclei. This will terminate movement at intended time, with no overshooting or oscillation. Damping function is achieved.

IV-Lesion: overshooting, dysmetria, kinetic tremors

❖ Cerebellar circuits:

- Cerebellum receives 2 types of afferents:

  1. **Climbing fibers:**
- They arise from the **inferior olivary nucleus** and excite the purkinjie cells directly. They project to the primary dendrites of the purkinjie cell, around which it entwines like a climbing plant.

- They exert a **strong excitatory effect** on single purkinjie cells.

2. **Mossy fibers:**
   - They excite the purkinjie cells in-directly by stimulating hundreds of granular cells. Then granular cells parallel fibers excite **hundreds of purkinjie** cells.
   - Each parallel fiber input makes a minute input. So, large number of mossy fibers must be stimulated simultaneously (**spatial summation**) to excite the purkinjie cells.

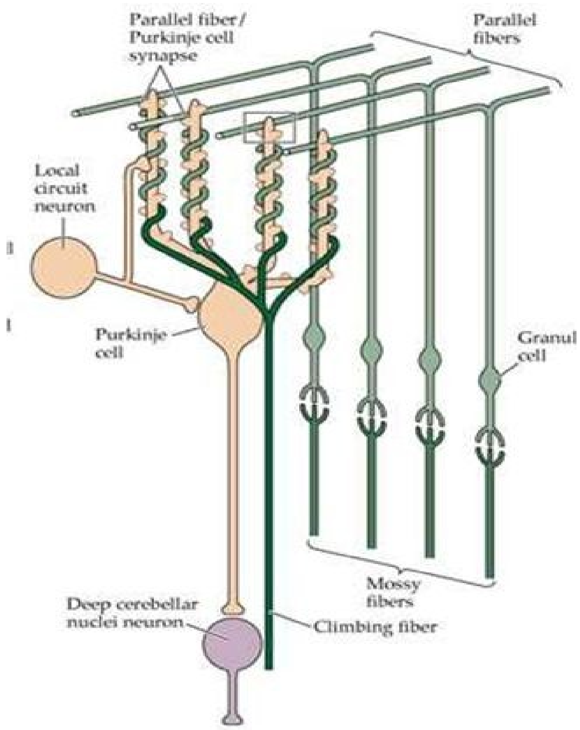


Figure (2):Climbing and mossy fibers

- Deep cerebellar nuclei are the main cerebellar output. Deep nuclei are excited by afferent collaterals and are inhibited by purkinjie cell fibers. Normal balance during rest is in favor of excitation, with excitatory signals to cerebral cortex.

- To limit the duration of excitation by any afferent, there are inhibitory circuits in the cerebellum that are stimulated by the small parallel fibers of the granular cells.
- **Golgi interneurons:** their axons mediate **negative feedback inhibition.**
- **Basket cells and stellate cells:** They send their axons at right angles across the parallel fibers and cause lateral inhibition of adjacent Purkinje cells, thus sharpening the signal. This is called **negative feed forward inhibition or lateral inhibition.**

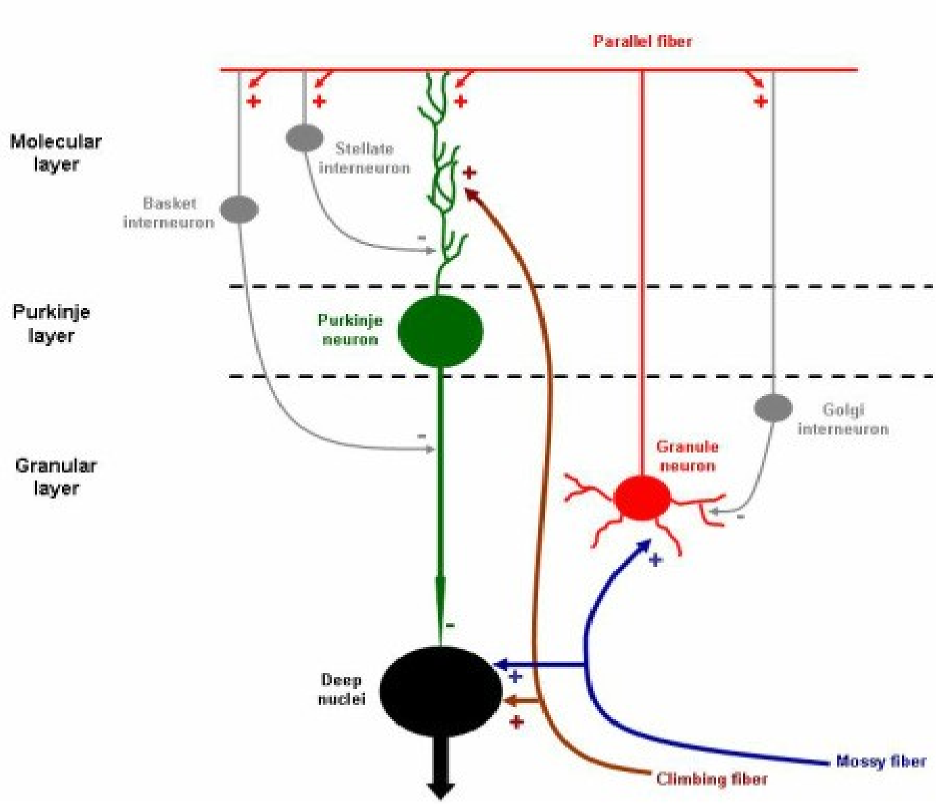


Figure (3): cerebellar inhibitory circuits

Cerebrocerebellum

Physiological function:

1-Planning of voluntary movement {feed forward control before action is taken}

a- Planning of sequential movements

- It is connected to premotor area, sensory cortex

-It provides plan of sequential movements required to execute intended voluntary movement. It adjusts the final motor command before it is discharged to the lower motor centers.

- It generates the motor command of the next movement at the same time current movement is still executed. So, the movements progress smoothly and rapidly.

b- Timing of sequential movements

Provide proper timing for each movement

C Prediction: especially in (rapid movements)

- **Receives**
- Inputs from all sensory organs so it is informed about rate and direction of movement
- **computes**
- change in rate, timing and direction of movement to reach a certain goal at certain time.
- Predict from a changing visual scene how rapidly person approaches an object
- When a person run towards a wall, this function enables him to stop before reaching the wall without hitting it.

Non motor functions of cerebellum:

- The olivocerebellar pathway projects to the cerebellar cortex via climbing fibers.
- The inferior olivary nucleus act as an error detector and are responsible for motor training (learning):

***Inferior olivary nucleus receives*:**

1- Intended motor plan from motor cortex

2- Actual movement from contracting muscles

Compares both information

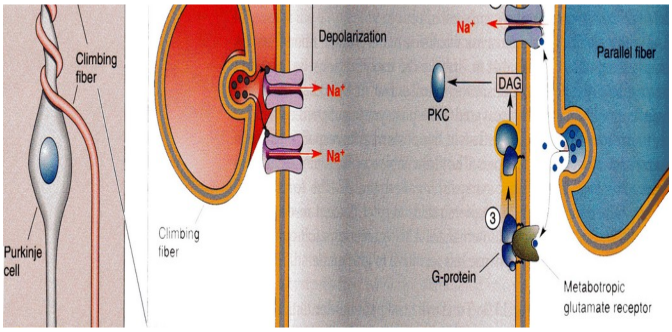
Match= normal rate of firing of climbing fibers=1Hz/sec

Mismatch {during training} {learning new task}:

-When particular action goes off target the inferior olivary nucleus neurons are activated.

Send climbing fibers

- Climbing fibers firing rate increases when a new movement is being learned. They change the sensistivity of purkinjie cells to mossy parallel fibers activity.



Regulation of muscle tone and postural adjustments:

Cerebrocerebellum: excitatory	Spinocerebellum: inhibitory
The predominant effect is facilitatory so cerebellar lesions lead to hypotonia	

Cerebellar stretch reflex:

- Stimulus: When a contracting muscle meets an unexpectedly load
- **Inputs:** spinocerebellar tracts from muscle spindles
- **Output:** to reticular formation, then reticulospinal and vestibular nucleus then to vestibulospinal tracts that affect γ motor neurons.
- Gives additional support to spinal stretch reflex

Cerebellum functions are summarized:

1. Regulation of body posture, equilibrium
2. Servo-comparator function
3. Damping function
4. Coordination of rapid ballistic movements
5. Planning of sequential movements
6. Timing of sequential movements
7. Prediction
8. Regulation of muscle tone and postural adjustments

9. Motor learning

Cerebellar dysfunction

Cause: vascular lesion, trauma, tumor in 8deep cerebellar nuclei

Effects: on **same side** of lesion

1-Asthenia: loss of potentiating effect of mossy fibers

2-Hypotonia: loss of facilitation of neo-cerebellar discharge

pendular knee jerk:

knee jerk is weak , leg falls like a dead weight by hypotonia and swings for sometimes like a pendulum

3-Motor ataxia: *Incoordination* of the voluntary movements specially toward the rapid movements due to error in the rate , range , force and direction of movement, in *absence of paralysis.*

1-Asynergia:

Inability to perform two voluntary acts at the same time i.e. during writing patient can't flex fingers and extend wrist joint at the same time.

2- Adiadikokinesia:

Inability to perform **rapid, opposing and alternating** movements.

- Due to loss of the predictive function. i.e. patient can't do pronation followed by supination rapidly.

3-Nystagmus:

-Rhythmic rapid involuntary movement of eyeballs or Tremor of the eyeballs that occurs usually when one attempts to fixate the eyes on a scene to one side of the head

-Impaired amplitude of saccades (saccade dysmetria) or impaired gaze holding function (horizontal or downbeat nystagmus)

Mechanism:

- Failure of damping

-Dysfunction of the pathways connecting the flocculonodular cerebellum with the vestibular nucleus and medial longitudinal bundle

4- Dysarthria: scanning or stacatto speech

Cause: decomposition of movements, loss of coordination and prediction of buccal, laryngeal, and respiratory movements

5- Dysmetria: **hyper or hypometria**

Error in range and direction of movements, inability to control distance of the voluntary movements.

6- Tremors (kinetic tremors): intentional tremors:

-Coarse tremors increases as the limb reaches the intended point.

- It appears during voluntary movements and disappear during rest or sleep (**unlike parkinsonism**).

Cause: loss of damping function of the cerebellum.

7-Decomposition: of movements due to loss of coordination function.

8- rebound phenomena: Patient cannot stop movement in desired point, examined by arm pulling test.

9- Gait: Drunken gait or zig-zag like gait. Gait is characterized by wide based stance, cannot walk straight or turn quickly.

10- Heel to shin test:

It is a measure of coordination, asymmetric heel to shin test is highly suggestive of an ipsilateral cerebellar lesion.

Sensory ataxia	Motor ataxia
Propioception loss	
Positive romberg sign	No romberg sign
Compensated by vision	not affected by vision
No tremors	Intention tremors
No nystagmus	nystagmus
	Dysarthria staccato speech
Stamping gait	Drunken gait
Lesion in dorsal column	Neocerebellar lesion

signs of cerebellar dysfunction

- Asthenia
- Hypotonia
- Dysmetria
- Kinetic or intention tremors
- Dysdiadochokinesia
- Decomposition of movements
- Dysarthria
- Nystagmus
- Asynergia
- Disturbance of gait
- Rebound phenomena